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A Proposed Template for BW Response

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ABSTRACT

The Domestic Preparedness Program funds initiatives to improve the ability of U.S. communities to respond more effectively to terrorism by weapons of mass destruction. One of these initiatives is the Biological Weapons (BW) Improved Response Program. This program is developing a response template for cities to tailor and incorporate into their emergency response plans for use in case of an incident involving biological agents. The response template consists of a number of components, such as command and control, epidemiological investigation, and several medical response components.

This paper describes the proposed BW response template and a validation process using operations research methods and tools. The paper then shows how the validation process will be used to evaluate one of the template components: the Neighborhood Emergency Help Center (NEHC).

The NEHC is a key component of the medical response portion of the template. The purpose of the NEHC is to serve as a temporary neighborhood clinic, providing triage and stabilization treatment to casualties close to their own homes. Under the NEHC concept, casualties requiring hospital care are transported to acute care centers. Those who are able to return home are given appropriate medications and instructions.

In order to validate the NEHC component, a working group of emergency medical experts developed a detailed facility design, including staffing and casualty process flow. They also developed descriptions of a primary scenario, casualty profiles, and triage and treatment

protocols. The primary scenario is a moderate-sized BW incident involving a non-contagious agent. These descriptions were entered into a verified simulation model of the NEHC design to predict performance. Performance was predicted in six areas: facility throughput, casualty cycle time, staff utilization, treatment efficacy, disposition of casualties and casualty data completeness.

NEHC performance will be tested via a desktop exercise with an independent panel of emergency medical experts and a live field test using trained medical staff and actors portraying casualties. The outcomes of these exercises will be compared to the simulated performance to validate the component.

BACKGROUND

This paper describes the Biological Weapons (BW) Response Template and the validation process for a key template component: the Neighborhood Emergency Help Center (NEHC). This work was performed under the auspices of the Domestic Preparedness (DP) Program. The paper briefly describes the DP Program, the Biological Weapons Improved Response Program (BWIRP), and development of the BW Response Template. The paper then presents the validation methodology being used to test and evaluate the NEHC component of the template. The testing will be on-going during FY 99 and FY 00. Interim test results will be presented at the next MORS Symposium in June 2000.

Domestic Preparedness Program

In response to growing concerns regarding domestic terrorism, the 104th Congress included in the National Defense Authorization Act for Fiscal Year 1997 a new, multiyear program to provide our nation's communities with training regarding emergency responses to weapons of mass destruction and to test ways to improve the responses of Federal, State, and local agencies to emergencies involving biological and chemical weapons.

As a result of this act, the U.S. Army Soldier and Biological Chemical Command of the Department of Defense, in partnership with the Department of Health and Human Services, the Federal Emergency Management Agency, the Federal Bureau of Investigation, the Environmental Protection Agency, and the Department of Energy, developed the Biological Weapons Improved Response Program. The purpose of the program is to identify, evaluate, and demonstrate the best practical approaches to improve the preparedness of US cities from an attack of biological warfare agents. The BWIRP's objectives are to assess the BW response problem, formulate an integrated approach to BW emergency response (including federal, state and local assets), and identify gaps and improvements in response capabilities. A companion Chemical Weapons IRP is focusing on enhancing responder protection and detection and on mass casualty decontamination.

BW Response Template

A multi-agency team comprised of over 60 experienced and working emergency responders and managers and technical experts from local, State, and Federal agencies from around the nation was assembled to develop the BWIRP. There were two primary products from the team's work in 1998: a BW Response Template and a prioritized list of response gaps and response improvement concepts.

The BWIRP team concluded that the overriding consequence of a large-scale unannounced BW attack will be the rapid emergence of large numbers of casualties. Response systems need to anticipate and be robust enough to deal with this probability. As much as possible, a response system should be able to detect and identify the medical problem at the earliest moment, administer appropriate medical prophylaxis to avoid disease in exposed victims, and then be able to keep up with the onset of casualties so that all are dealt with in a supportive and non-chaotic manner. If the attack involves high doses of a lethal disease, the ability to save many of the casualties exposed, even with immediate medical treatment, will be diminished. Therefore, the response systems should have the capability to deal with high numbers of fatalities. Casualties from an attack on a subway or building could be dispersed over wide metropolitan, multi-state, or multi-national areas. Conversely, an outside release against a residential area could result in severe incapacitation of entire apartment complexes within one geographic location.

In short, a large-scale BW attack would result in a catastrophic medical emergency. Such an emergency would quickly saturate local emergency response and medical assets unless plans to cope with such an incident are in place beforehand. Such plans do not exist at this time for most cities. The problem then becomes: What would be an effective strategy for a city to cope with a BW attack, and how could that strategy be integrated across State and Federal levels?

The BWIRP team identified the need for and proceeded to formulate a generic BW Response Template that embodies the concepts and the specific activities that a city could perform to respond effectively to a BW incident. The template is a listing of activities that would need to be performed to respond to major BW terrorist incident. These are organized into groups referred to as components of the response template. Together template components represent an integrated response system. The team developed timelines for each response activity in order to see how the activities could work together to deal with the dynamics of the onset of casualties for different attack scenarios. The team then analyzed the personnel and material resources needed to perform each response activity. Lastly, the team estimated the sources and timing of personnel resources from local, State, and Federal assets in order to determine the overall practicality of the response template and identify shortfalls. Throughout, the team took a "bottom up" approach and let the problem drive the solution.

The template could be used by any city as a starting point to formulate its local plans, protocols, and preparations to respond to a BW incident. The template offers the following advantages:

- It is a useful format through which to share the results of the in-depth analyses performed here with other cities to assist them in determining how they would respond to a BW attack.

- Commonality in response concepts and medical modules among all cities could be enhanced if they started their planning from a common response template. This commonality would facilitate the rapid and efficient augmentation of the city's assets with State, regional, and Federal assets when responding to a large-scale BW attack. It could also facilitate stronger mutual aid agreements among adjacent localities.

- The template appears to have application to any catastrophic medical emergency. Its adaptation by a city would significantly enhance its overall emergency preparedness.

DEVELOPMENT OF THE NEHC

This section provides background on the development of the BW Response Template and the NEHC concept.

BWIRP Workshops

The BWIRP team conducted a series of workshops in 1998 to examine the BW problem and to start to develop response solutions.

Table 1

Scenario/Agent	Casualties	Fatalities
Francisella tularensis	1,100	380
Staphylococcus Enterotoxin B w/ Francisella tularensis	22,500	10,000
Bacillus anthracis	126,000	120,000
Venezuelan Equine Encephalitis	1,300,000	13,000
Rift Valley Fever	48,000	250

Each workshop focused on a selected BW terrorist attack scenario, with varied BW agents and covert delivery means. The BW agents and predicted outcomes are shown in Table 1.

The examination of this range of BW attack scenarios and expected impacts helped identify a number of issues for consequence management, including:

- Rapid and large scale emergence of casualties
- Potential for high number of fatalities
- Geographic dispersion of casualties
- Likelihood of public hysteria
- Difficult to diagnose illness/agent
- Scene of attack not readily identifiable
- Residual hazard is agent dependent

BW Response Template Components

With these issues in mind, workshop participants examined and developed response activities designed to mitigate the emerging consequences of the scenarios. The product of this effort was a BW Response Template—a work breakdown structure of specific activities that a city could perform to respond effectively to a BW incident. The BW Response Template was designed to be flexible, consisting of multiple diverse components, and encompassing and combining such aspects as epidemiological surveillance, criminal investigations, and medical response.

The BW Response Template can serve as a useful point of departure for cities and communities in preparing their plans to respond to a BW terrorist attack. Major components of the generic BW Response Template are depicted in Figure 1. Five key operational decisions made by city officials will drive the response. These operational decisions divide the response template into three phases: continuous surveillance, active investigation, and emergency response. These phases may overlap and occur concurrently, as would other crisis and consequence management activities.

The components, described in the 1998 BWIRP Final Report, are designed to work together as an integrated BW response system.

Modular Emergency Medical System (MEMS)

As described previously, a BW agent terrorist attack is likely to produce a large number of casualties combined with possible public hysteria. The massive amount of casualties and worried well that are anticipated from a BW incident would likely overwhelm existing hospitals and medical facilities. The BW Response Template addresses this problem through the Modular Emergency Medical

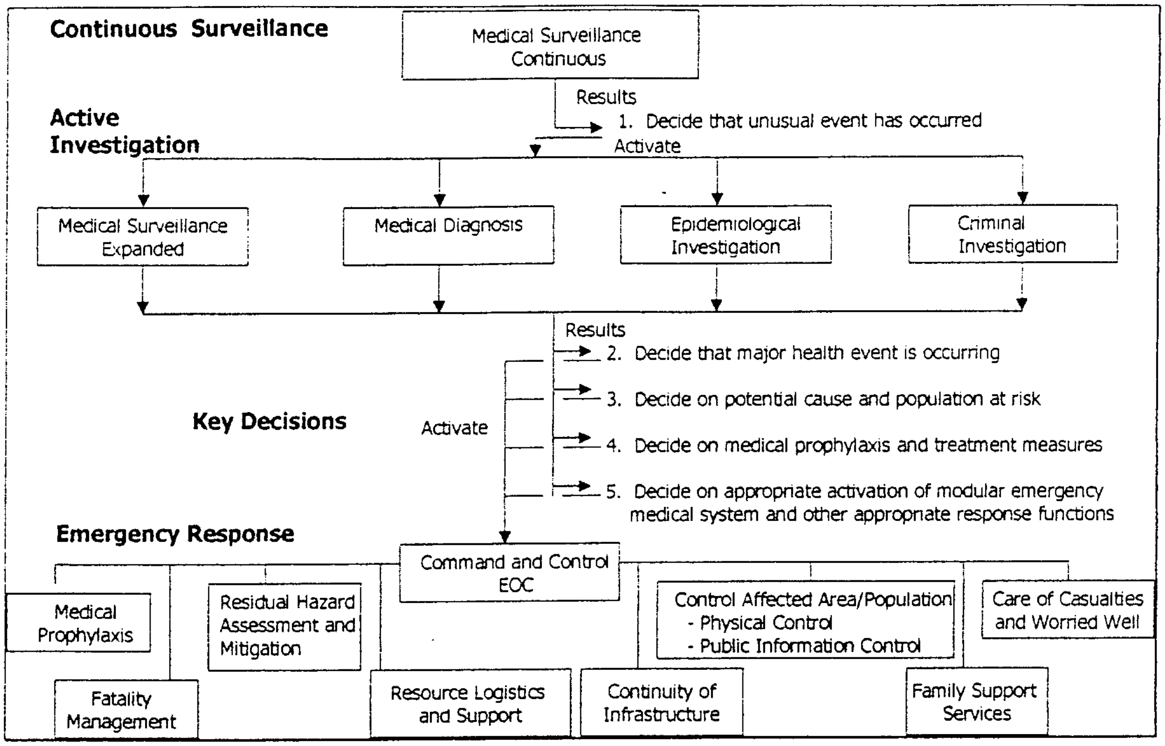

Figure 1: BW Response Template

System (MEMS), which is designed to provide relief to the existing medical system by setting up a distinct organizational structure to efficiently process and coordinate the flow of casualties. The MEMS concept is shown in Figure 2.

Management of this system is based on the Incident Command System/Incident Management System (ICS/IMS) that is currently used by the emergency response community. The Modular Emergency Medical System is based on the rapid organization of two types of expandable casualty care modules which can be added to or removed from the system as needed—the Acute Care Center (ACC) and the NEHC. These modules are linked to an area hospital that oversees casualty care, medical logistics and information flow. Together, these two modules have the capacity to care for 4000 casualties (comprised of incident casualties, the worried well and the normal patient population).

The current medical system includes public and private area hospitals, clinics, ancillary care organizations and private physicians. These components can be integrated and expanded during emergency operations by activating pre-planned communication and coordination links between components and the application of additional resources as shown in Figure 2. Area hospitals will form their own internal emergency Medical Command Centers (MCC) to coordinate all sector health care operations. ACCs are established in buildings close to the area hospitals to provide definitive and supportive care to acutely ill BW casualties that exceed hospital capacity.

Existing clinics are expanded into NEHCs and provide the primary point of entry into the

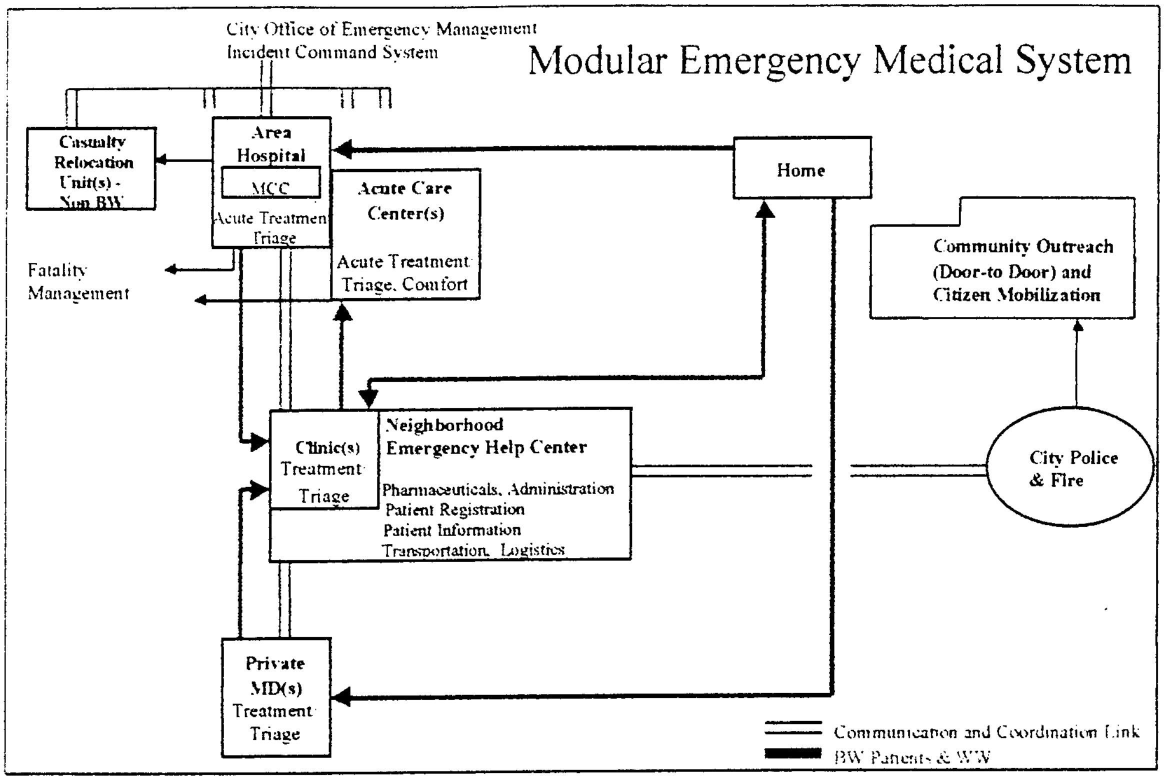

Figure 2: Modular Emergency Medical System

emergency medical system for BW casualties and worried well. Community outreach personnel and local volunteers will be used to assist the medical staff in these centers. Private medical doctors will send their BW casualties and worried well to these NEHCs. A sector outreach will be performed by police, firefighters, community health personnel and other officials to link home bound casualties to the NEHCs. If the ACCs and clinics become overwhelmed because of the extreme numbers of casualties, the police, community health personnel and other available officials, will distribute information, appropriate medication (after being triaged by trained medical personnel), and medical supplies to victims at their homes. They will also provide limited medical care by mobilizing a citizen home care effort.

Casualty Relocation Units will transfer non-BW hospital patients to remote locations in order to provide additional hospital space for BW casualties. During emergency operations, the area hospitals, clinics and private medical doctors will forego their autonomy and jurisdictional medical statutes and function as an integrated system. The individual area hospitals and their associated centers will be linked to the integrated Incident Command System to form a community-wide MEMS. In an alternate structure, Acute Care Centers and Neighborhood Emergency Help Centers could be established as stand-alone units not associated with area hospitals. Coordination of these Centers would then occur through the Community ICS.

The MEMS concept can be flexibly applied depending on the severity of the situation and the resources available within the affected community. The participating medical organizations will need to be pre-designated into community sectors. Locations for these facilities should also be pre-selected to assist the community to respond quickly and effectively to a BW or a CW event, or other emergencies involving massive amounts of casualties. Furthermore, the community's MEMS would provide a framework into which State and Federal resources could be quickly integrated to expand and sustain local emergency operations. The dynamics and logistics of establishing and sustaining this system and the application of local, State and Federal resources are still being assessed.

NEHC Functions

During emergency operations, a community's Office of Emergency Management (OEM) may activate the MEMS mass care strategy. Part of this plan calls upon pre-existing clinics and ancillary care organizations to expand their capabilities by mobilizing and integrating a community's available medical resources to become NEHCs. By augmenting these facilities with additional resources they can function as high-volume, community-based emergency health care centers. Depending on the community, these centers may or may not be affiliated with a hospital, and may or may not be physically attached to a hospital. The NEHC is designed, organized, equipped, and staffed specifically to provide basic medical services for those affected by an incident involving a BW agent.

The NEHC serves two primary purposes. The first is to function as a community triage point where casualties can quickly enter the medical system. This will help direct casualties away from emergency departments and allow hospitals to continue functioning. This will also help coordinate the massive victim tracking effort.

The second function of the NEHC is to provide initial evaluation and treatment, along with self-help information and instruction. Each NEHC is organized to process 1000 casualties per 24-hour period. A staff of 82 physicians, nurses, administrators, prehospital care providers, medical clerical personnel and volunteers is required to operate this facility. In addition to providing a mechanism for the mass distribution of medications and basic treatment, the NEHC includes transfer agreements for movement of casualties to a hospital or ACC. The community OEM is responsible for ensuring that adequate medical transportation and logistical support is provided to each of the centers to initiate and sustain operations.

NEHC Structure and Process

The NEHC is organized into seven primary triage, treatment and administrative areas, and casualties are processed through the facility on a priority basis. See Figure 3 for the NEHC process flow.

Initial Triage Area

Initial Triage takes place as casualties enter the facility. A team of Emergency Medical Technicians (EMTs) assesses the casualties immediately upon their arrival to the center. After passing a visual assessment, all ambulatory casualties are categorized "minimal/green" and instructed to proceed to the NEHC Registration Area. All non-ambulatory or obviously acutely ill casualties are evaluated for respiration, perfusion, and mental status. They are assigned priorities of care: "immediate/red", "delayed/yellow", or "expectant/black" and transported directly to the Treatment and Stabilization Area, bypassing registration. Overall, the NEHC will employ a triage

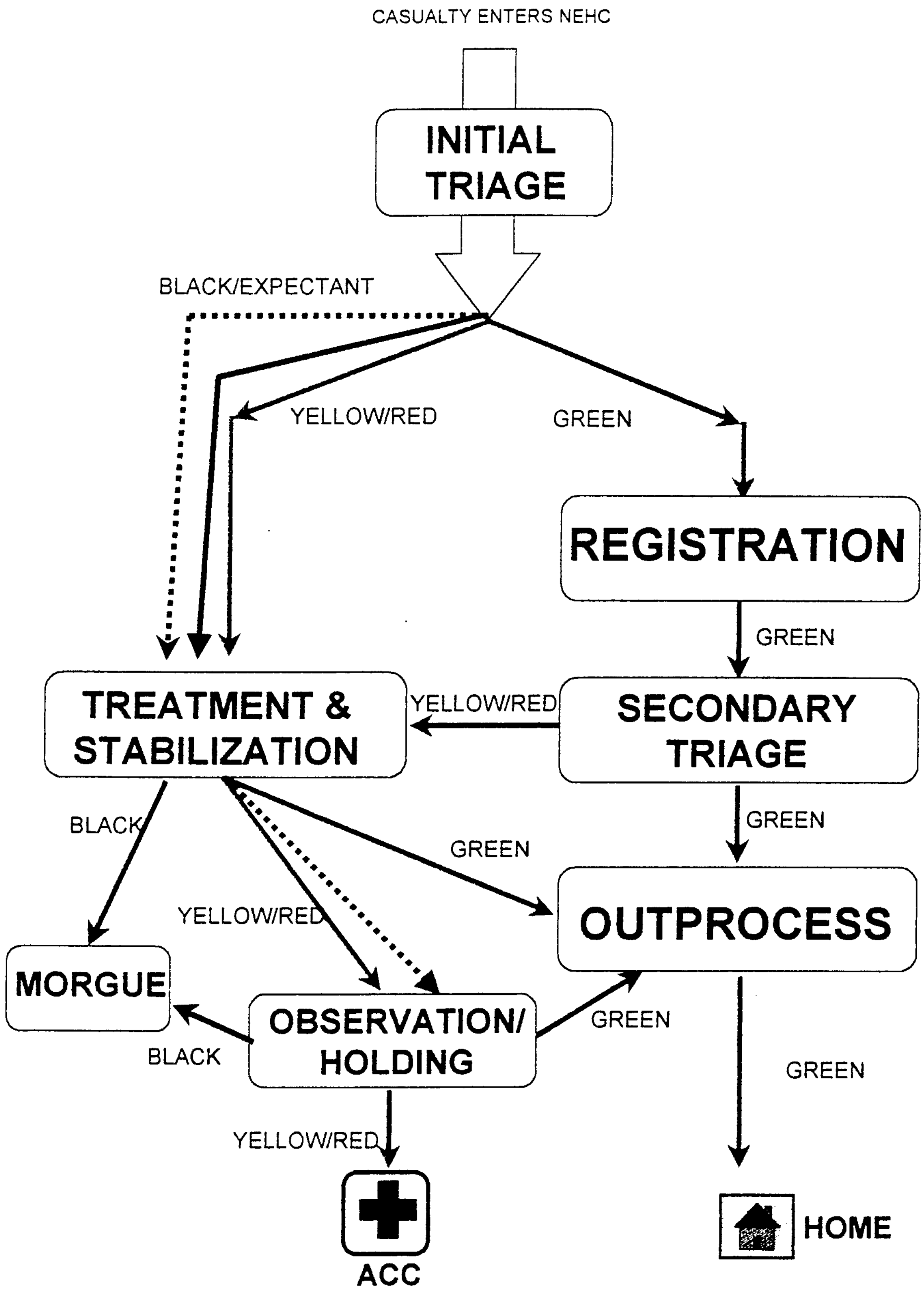

Figure 3: Neighborhood Emergency Help Center

protocol that strictly sorts casualties into four categories.

Immediate (RED tag) are those who need emergency life saving treatment. These casualties will have priority for treatment and transportation to the advanced care facilities.

Delayed (YELLOW tag) are those who require limited medical intervention for stabilization and whose condition permits some delay in therapy.

Minimal (GREEN tag) are those casualties who may or may not require treatment. They most likely will receive prepackaged pharmaceuticals, general self-help information, and be discharged or referred to their private physician.

Expectant (BLACK tag) are those that arrive deceased or are expected to die prior to transport to an advanced care facility.

Registration Area

Casualties who are well enough to be interviewed are registered by a team of clerks and volunteers. Each casualty is given a Patient Record Form that is used to record information and treatment in each area.

Secondary Triage Area

Following registration, casualties are reassessed and possibly recategorized at the Secondary Triage Area. They are assessed for five vital signs (temperature, respiratory rate, blood pressure, pulse rate and blood oxygen) and five critical assessment markers (alertness, photophobia, stiff neck, breathing, and chest pain).

Out-Processing Area

Casualties not requiring care beyond prophylaxis and self-help information are directed to the Out-processing Area. Casualties sent to the Out-processing Area are given an instructional briefing, issued prophylaxis, and discharged. Discharge will include collection of casualty records and referral to psychological counseling or other human relief services.

Treatment and Stabilization Area

Severely ill casualties or those identified as needing additional medical care during Secondary Triage are categorized "immediate" or "delayed," and forwarded to the Treatment and Stabilization Area. Casualties are treated according to an established protocol that includes Advanced Cardiac Life Support (ACLS), Advanced Trauma Life Support (ATLS), burn management, and Pediatric Advanced Life Support (PALS) care.

Observation Holding Area

Following initial stabilization and treatment, casualties are transferred to the Observation/ Holding Area. Casualties considered unsalvageable/expectant are forwarded to the Observation/ Holding Area and monitored, until all casualties assigned "immediate" priority have received care. All other casualties transferred to the Observation/ Holding Area will continue treatment while under medical supervision. Casualties requiring in-patient care are transferred once they have been stabilized within the limitations of the NEHC capabilities. In some instances, casualties moved from the NEHC may not be clinically stable due to severity of their condition, limited medical resources and time constraints. Casualties whose condition allows may be released from the Observation/Holding Area for out-processing.

Temporary Morgue

Deceased casualties are pronounced dead by a Stabilization Team Physician and forwarded to the center's Temporary Morgue.

NEHC Staffing

An enormous amount of casualties seeking treatment will cause hospitals to recall a large portion of a community's emergency medical personnel. This will cause a shortage in available skilled providers. Such an event may leave few qualified emergency medical personnel to staff the NEHC. For example, the types of physicians that will likely staff the NEHC will be family practitioners, dentists, dermatologists, and/or gynecologists. These physicians may not have used their emergency medicine skills in many years and some may never have seen the inside of an Emergency Department. They may not be current in treatment regimes or have the ability to administer intravenous lines, "run" a cardiac arrest, or even recognize symptomology of a life threatening illness.

Therefore, a team approach is used whenever possible to allow the staff to assist each other. There are six types of staff who will interact with casualties.

Physicians

Physicians are responsible for the medical care provided in the NEHC. This includes the medical evaluation, diagnosis, and assigning treatment and disposition of the casualty, as well as the direction and coordination of all other care provided to the casualty. Physician Assistants/Family Nurse Practitioners may also fill this role.

Nurses

Nurses are responsible for the nursing care of casualties, including assessment planning and evaluation of response to medical interventions. They must possess appropriate credentials. They must be able to provide evidence of patient care experience. They must possess and show evidence of the knowledge and skills necessary to deliver respective levels of care. Physician Extenders may also fill this role.

Paramedics

Paramedics provide skills that are similar to nurses, but they may have less experience. Paramedics must also possess appropriate credentials.

EMTs

These technicians are responsible for triage and providing assistance to the nursing staff in the care and treatment of casualties in the NEHC. They must possess current certificates and/or licenses to practice. They must have experience in the medical field using their certificate/license. This category also includes nurses assistants.

Medical Clerical Personnel

The clerks in the NEHC are responsible for generating the paperwork necessary to run an NEHC. They are the facilitators who coordinate moving casualties through the NEHC. They are responsible for answering phones and ensuring that all communications are carried out throughout all the stations and other modules in the MEMS. They are required to have some experience in medical responsibilities and understand medical terminology. Lastly, they are responsible for supervising the volunteers in their sections.

Volunteers

Volunteers will assist in performing registration, internal transportation, and outprocessing. They also assist the medical staff in recording casualty information in the secondary triage and treatment areas.

VALIDATION APPROACH

One of the objectives of the BWIRP is to demonstrate that the BW Response Template performs as intended, or is "valid." To determine how well the template works, the program began a test and evaluation phase in 1999. The NEHC will be the first template component assessed. The remainder of this report describes how the NEHC concept will be validated.

Validation testing is a new approach in a disaster medicine community that is used to conducting readiness exercises. In a readiness exercise, the purpose is to find out how well test participants follow certain procedures or react to events. However, in these template validation tests, the purpose is to find out, "will the template perform as expected?"

The validation approach was developed to determine whether the NEHC, the first template component, would perform as expected. The approach is based on operations research methodologies, and involves four major steps:

- Step 1: Establish specific performance expectations.
- Step 2: Gather data and measure actual performance.
- Step 3: Compare actual to expected performance.
- Step 4: Draw conclusions and recommend improvements.

Step 1 involved helping the BWIRP team and the working group to develop measures of effectiveness, a primary scenario, a process flowchart, probability trees and a simulation model of the NEHC concept. This allowed the working group to state specific performance expectations of the concept.

In Step 2, two evaluation protocols will be used to gather data and measure actual performance. Actual performance data will be gathered though a live field exercise, in which a facility will be set up with trained staff. Actors portraying casualties with various symptomologies will be processed through the facility in a scaled-down time sequence, and various performance data will be captured and analyzed.

The live exercise will be supplemented by another evaluation protocol, referred to as a desktop exercise. The desktop exercise will be used to validate aspects of the NEHC that cannot be tested in the live exercise by using a panel of independent emergency medicine and epidemiology experts.

In order to compare actual performance to expected performance, Step 3 makes use of a multi-attribute utility model that was built using the MOEs as criteria and the expected performance and actual performance data sets as alternatives.

Measures of Effectiveness (MOEs)

MOEs were identified early in the validation process. A complete set of MOEs would measure quantity and quality, and internal and external performance, as shown in Table 2.

Table 2: Categories of MOEs

	Internal	External
Quantity	Capability to process presenting casualties	System capability to process the population-at-risk
Quality	Impact on presenting casualties	System impact on the population-at-risk

The scope of the first year testing, however, was limited to "internal" performance only. Internal "quantity" MOE's were defined as the capability of the NEHC structure, procedures, and resources to process presenting casualties. For this analysis, three specific measures were identified: facility throughput, casualty cycle time, and staff utilization. The quantity MOE's will be assessed during the live field exercise.

Internal "quality" MOE's measure the resulting impacts of medical care received on the casualties actually processed through the NEHC. For this analysis, three specific measures were identified: treatment efficacy, triage disposition and casualty data completeness. The first two quality MOE's will be assessed during the desktop exercise and the last will be assessed during the live field exercise. The following are definitions of the six MOEs used in the NEHC validation process.

Facility Throughput

The number of casualties processed through the NEHC to be sent to the ACC or returned home in a 24-hour period. The BWIRP team established a design goal of 1000 casualties per day.

Casualty Cycle Time

The amounts of time casualties spend processing through the NEHC to be sent to the ACC or returned home. Overall cycle time is composed of the time transiting from one area to the next, the time waiting to be serviced by a staff member, and the time spent being serviced by a staff member.

Staff Utilization

The percent of time the facility staff is providing direct or indirect casualty services. The utilization is measured for each of the six types of staff. Direct care is the time actually servicing casualties. Indirect care involves administrative tasks. Any time not performing direct or indirect tasks is considered idle time.

Treatment Efficacy

The percent reduction of deaths due to casualty processing through the NEHC (mortality) and the percent reduction in effects or duration of illness due to casualty processing through the NEHC (morbidity).

Triage Disposition

The percentage of BW agent-infected casualties sent to the ACC and the percentage of non-infected casualties sent home. Not all infected casualties may be sent to the ACC, depending on the extent of the incident and the capacity of the acute care facilities. However, the greater percentage of infected casualties who are sent to the ACC, the less risk is placed on the infected population.

Casualty Data Completeness

The ratio of completed information items on the Patient Form to the items required to be collected.

<u>Primary Scenario</u>

The working group developed a specific baseline scenario for the validation test. The agent in the scenario is Tularemia, in aerosol form, used in a subway attack. The attack occurs during flu season and affects a normal cross-section of the population, to include elderly and children. Identification of the agent has occurred, and the NEHC is set up on day 4 after the attack, which represents the highest percentage of infected casualties (versus worried well).

Based on this scenario and output from a casualty generation model, the working group estimated various parameters to describe the casualty mix that would present to the NEHC. These parameters were used to predict casualty flows. The conceptual design specifies 1000 casualties in a 24 hour period, which equates to 42 per hour. This was assumed to be an exponential (Poison) casualty arrival distribution within each hour.

Presenting States of Infection

The percentage of casualty arrivals who will be infected on Day 4 was estimated and is shown in Table 3. Sequela is a lingering, chronic condition that may result from exposure to some BW agents.

Table 3: States of Infection

State of Infection	**Percent**
Not Infected (Worried Well)	33%
Infected, would die without treatment	7%
Infected, would have sequela without treatment	0%
Infected, would fully recover without treatment	60%

Presenting Conditions

The percentage of casualty arrivals who, given a particular state of infection, are dead on arrival, feeling severely ill, feeling mildly ill, or not feeling ill. These percentages are shown in Table 4.

Table 4: Presenting Conditions

State of Infection	**DOA**	**Feeling Severely Ill**	**Feeling Moderately Ill**	**Not Feeling Ill**
Not Infected (Worried Well)	0.5%	1.5%	11.5%	86.5%
Infected, would die without treatment	0.5%	50%	39.5%	10%
Infected, sequela w/o treatment	0	0	0	0
Infected, fully recover w/o treatment	0.5%	50%	39.5%	10%

Process Flowchart

After the MOEs were established, a flowchart of the processing steps intended for each casualty was developed. The Process Flowchart helped define the key activities and events in the NEHC design. A flowcharting tool called *Inspiration* was used with the working group experts to lay out the process flow of presenting casualties, and to help elicit and capture the specific process steps involved and detailed descriptions in a single model. The resulting flowchart is shown in Figures 4 and 5.

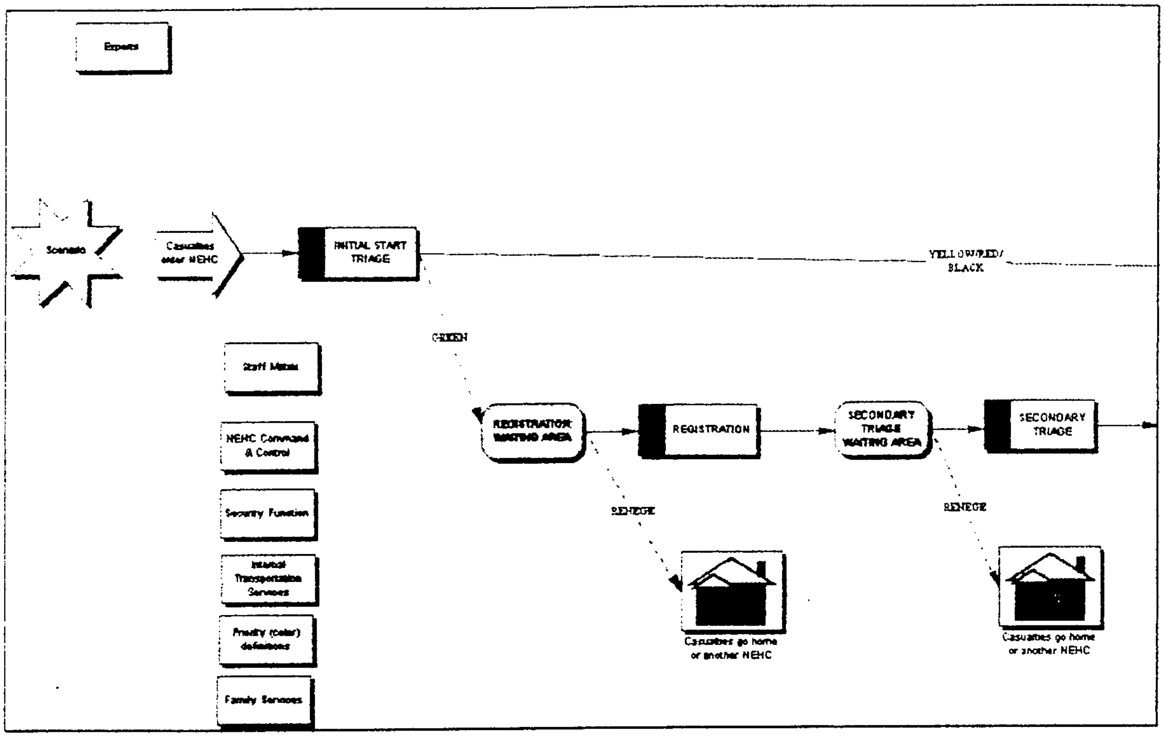

Figure 4: NEHC Process Flowchart (Part 1)

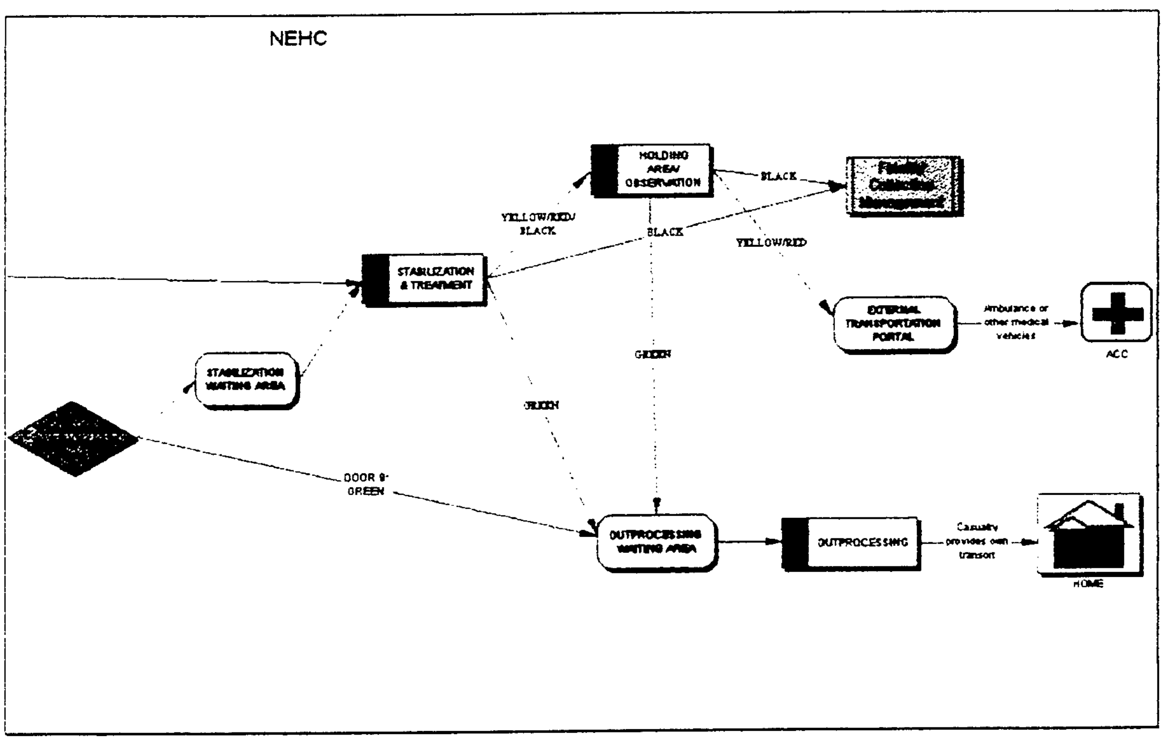

Figure 5: NEHC Process Flowchart (Part 2)

The process flowchart was very helpful to the working group in thinking through the specific areas, functions, and casualty paths that were merely implied in the template. When the group first met, there was no common understanding of what was going to happen inside the facility. The template only provided a work breakdown structure (WBS) format placed on a timeline that was not useful for designing the internal workings of the component. The process flowchart allowed the working group to focus on key design issues, such as numbers of triage stages and how best to register casualties.

For example, the working group first estimated processing times for each area while developing the process flowchart. These ranges are shown in Table 5.

Table 5: Processing Times

Station	**Time** (min)
Initial Triage	½ to 1
Registration	3-5
Secondary Triage	5-8
Treatment & Stabilization	15-45
Observation and Holding	45-60
Outprocessing – briefing	10-15
Outprocessing – discharge	3-4

The working group developed the flowchart in a collaborative effort in real time. The group made notes in the *Inspiration* software as they discussed each block, saving time and providing documentation. The members identified areas that they wanted to test and those that would not be tested. They also began to get an appreciation for the implications of the triage and treatment protocols that they would develop later. Finally, through the flowchart they were able to see the multiple paths the casualties would take through the facility and the dispositions of the casualties.

A particular concern in the design was that presenting casualties might leave the facility before completing the registration process if they had to wait to be seen. This behavior, known as reneging, was assumed to be a potential problem at registration and secondary triage. Once a casualty was told that he or she needed treatment, it was assumed that the casualty would not renege.

Simulation Model

Next, the casualty flow process was converted into a dynamic simulation model. A desktop simulation program called *Extend* was used to build a representation of the structure and processes of the NEHC. *Extend* is capable of both continuous and discrete event modeling. The NEHC simulation was built as a discrete event model, with each casualty represented as an item, and staff time represented as resource pools.

The model shows how different types of casualties move from area to area, the time it takes to process a casualty at each area, the staff time needed, and the expected dispositions of the casualties. The simulation output plots provide a view over time of the number of casualties processed through the NEHC facility and their dispositions, as well as staff utilization and the times to complete each activity. These are the expected values for the "quantity" MOEs discussed above. Figure 6 shows a portion of the simulation model.

The finished model also helped the working group examine the impacts of changing some of the design variables. For example, the secondary triage rules have a direct impact on the percent of casualties who will be sent to the ACC. The working group could vary the triage procedures, for instance, by requiring fewer positive symptoms before directing casualties to the ACC, and see the increase in the percent of casualties expected to be sent there. This factor has an enormous impact on

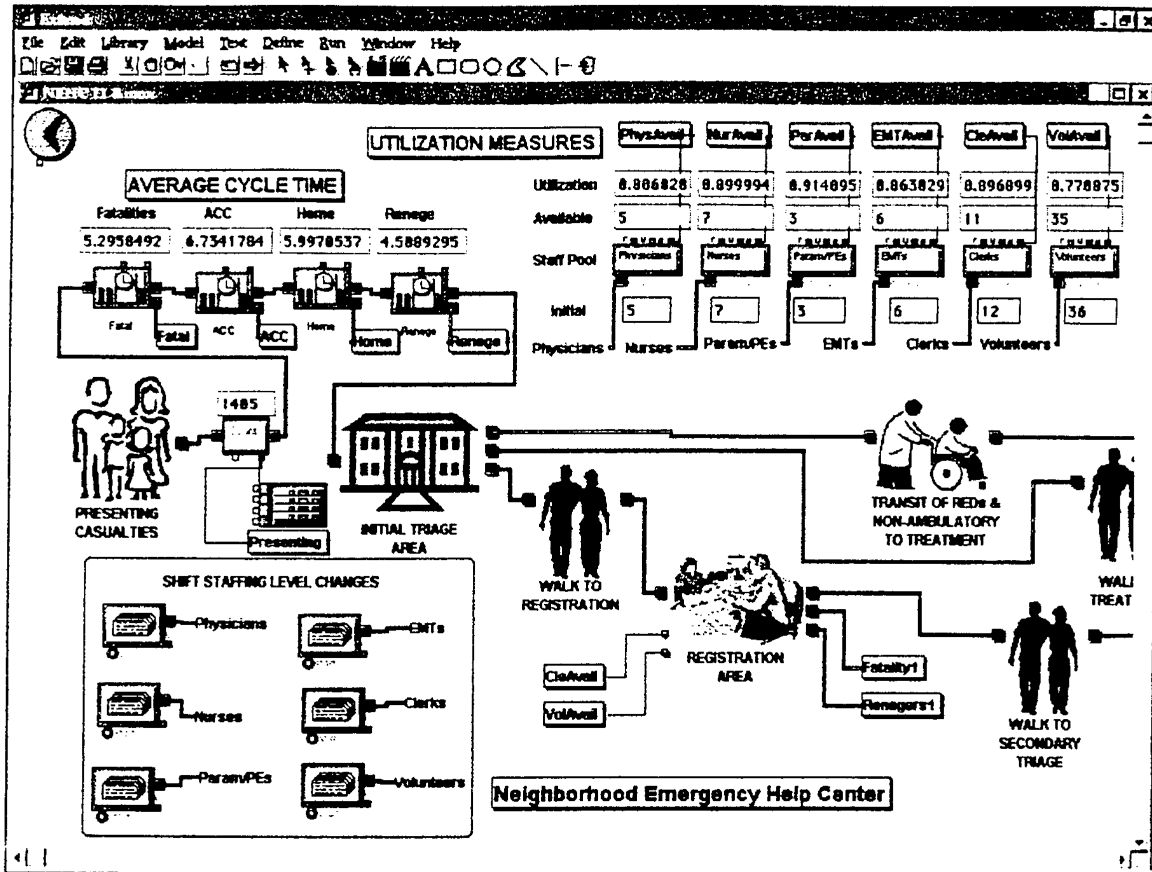

Figure 6: NEHC Simulation Model

the number of ACCs that would be required in a BW incident.

The process of building the simulation model proved as useful as the finished product. The questions raised by the modelers in their effort to accurately represent the concept helped the working group to refine the design. For example, additional paths were added for casualties who recovered sufficiently in the treatment and holding areas to be able to return home with medications.

The NEHC simulation model, and simulations of other components, have multiple uses for the BWIRP. First, they can help subject matter experts gain insights into the proposed component design. They can help suggest the appropriate measures and ways to collect the data during testing. They can be used to provide inputs to workshops and tabletop exercises. They can be used to test component performance in other situations which there may not be time or funds to conduct a live field test. Finally, they can be used to show cities and communities how the template concepts can be tailored to their unique circumstances.

Probability Trees

While many of the uncertainties associated with the NEHC design were included in the simulation model, such as arrival rates, activity times, and casualty dispositions, it was found that the simulation was not well suited to analyze the Efficacy MOE. This measures

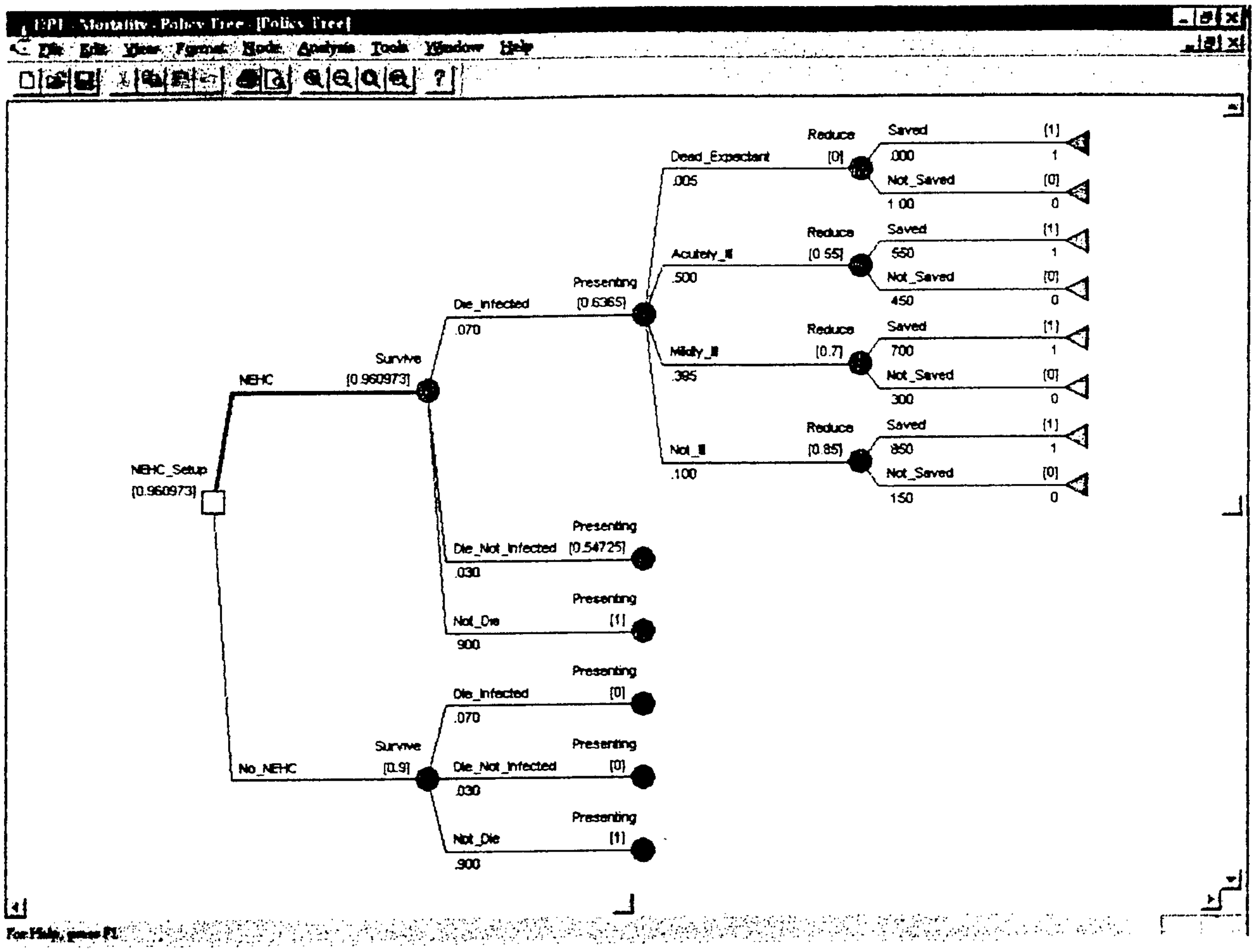

Figure 7: Mortality

the reduction in mortality and morbidity. Mortality is the rate of death resulting from the incident. Morbidity is the duration and severity of illness resulting from the incident. These measures were best modeled using a probability tree. Probability trees are special cases of decision trees. A decision analysis package called *DPL* was used. Figure 7 shows the probability model for reduction in mortality.

In this probability tree, the likelihood of a presenting casualty surviving the incident was subjectively assessed by the working group. Without the NEHC triage and treatment protocols, 90 percent of the presenting casualties will survive. However, given the expected distribution of infected casualties and their presenting conditions, the working group assessed a 96 percent survival rate with the NEHC. This represents a 60 percent reduction in fatalities. A similar probability tree was developed for morbidity reduction.

Multi-Criteria Decision Model

In the final step, the MOE's were combined to create a single overall measure of validity. Multi-attribute utility (MAU) analysis was used to structure the MOE's in the form of a hierarchy. Figure 8 shows the MAU model structure built using *Logical Decisions for Windows (LDW)*.

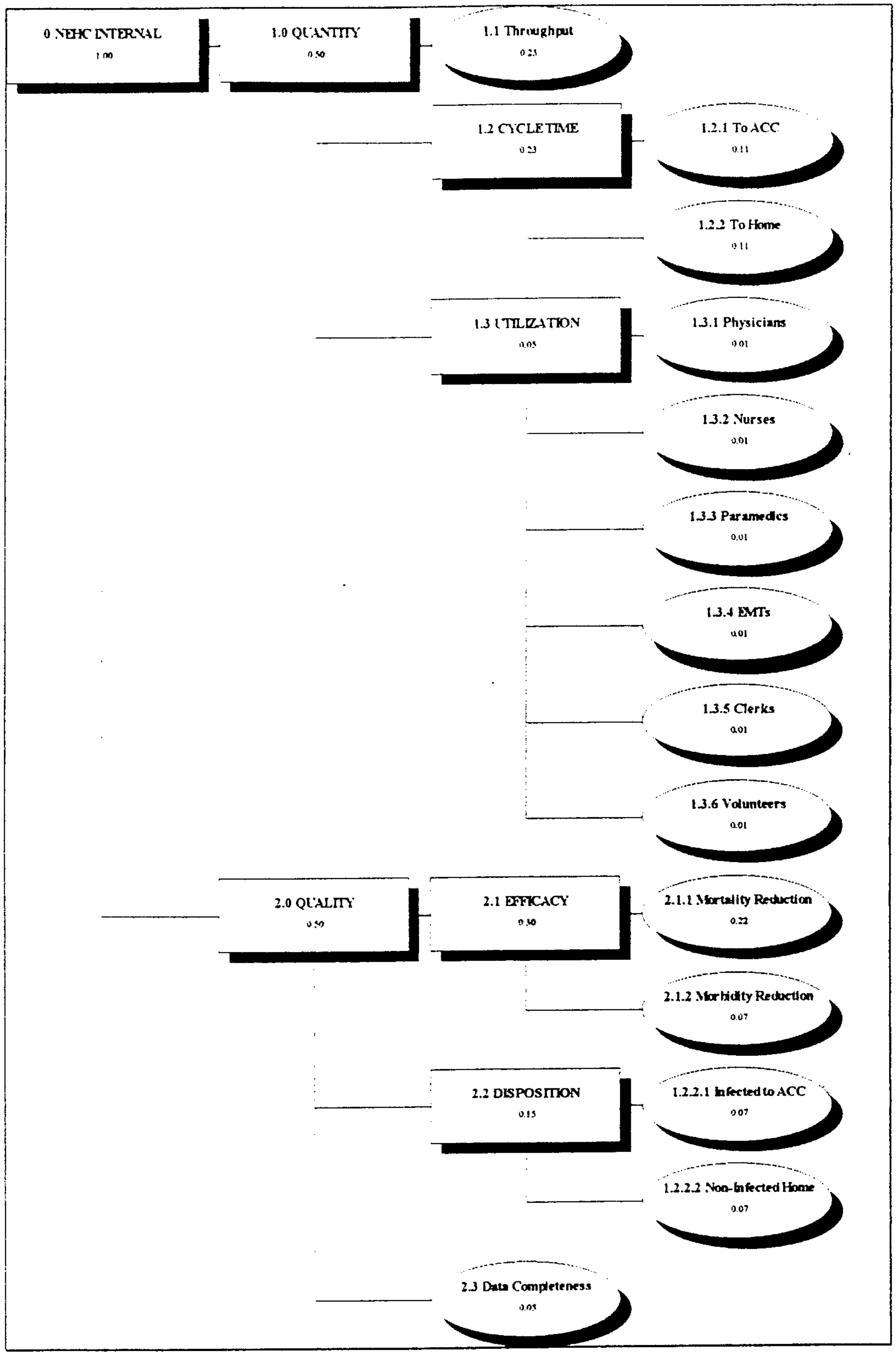

Figure 8: Multi-Criteria Decision Model

MAU is one of the primary decision analysis approaches to multi-criteria decision making (MCDM). MAU builds on traditional utility theory. The method scores alternatives on a set of criteria and then weights the criteria according to their importance in making the decision. For each alternative, the scores are multiplied by the criteria weights and then added together.

The working group developed performance scales for scoring and relative weights for each MOE. Figure 8 shows the global weights for each MOE. The expected performance of the NEHC in the primary scenario was established as the top of each performance scale. This allowed the model to represent the expected performance with an overall score of 100. The results of the various validation exercises will be entered into the model upon completion of the testing.

Since template component validity is a relative concept, the overall evaluation goal is to come as close to the expected or desired results as possible. In the example shown in Figure 9, the results of the exercise using the primary scenario and the first two alternative scenarios are quite acceptable, while the results of the last scenario indicate that there would be a problem applying the NEHC template component in this situation. Either the NEHC design must be modified to better accommodate this last scenario, or a policy established which calls for a different approach should this situation arise.

In addition to evaluating the overall validity of the proposed component design, the MAU model facilitates trade-off analysis among design parameters. For instance, the NEHC design may be improved by adding several more staff, possibly reducing the score on a

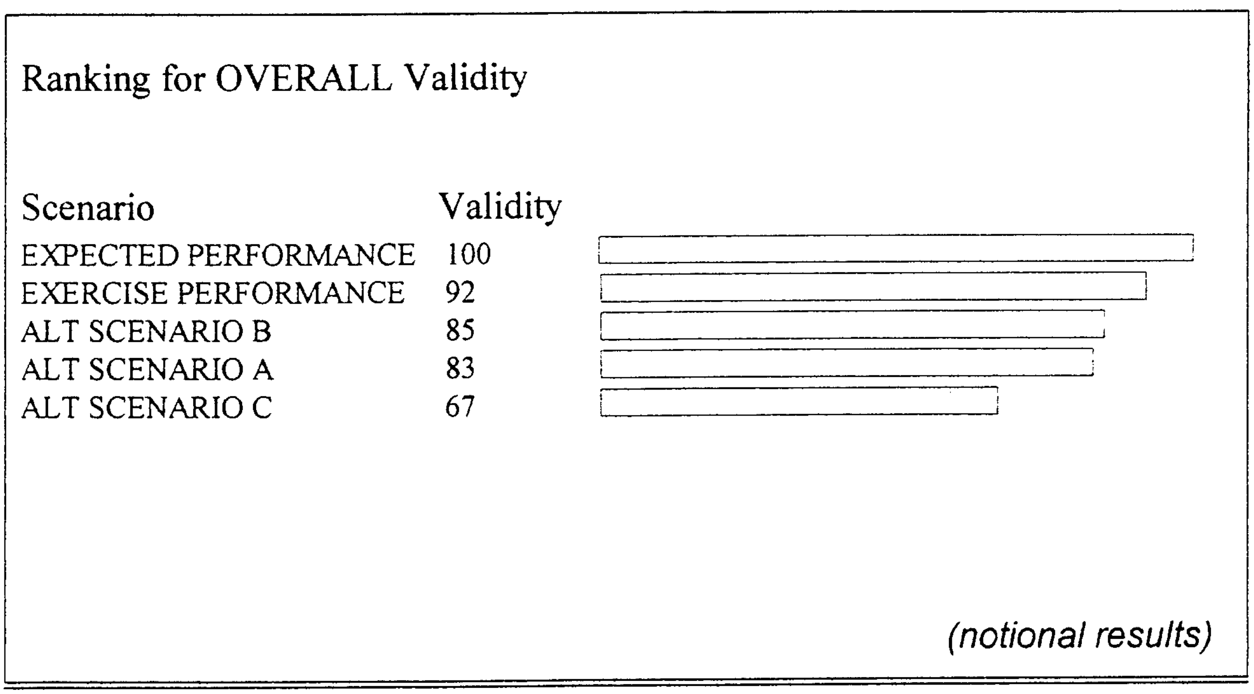

Figure 9: Overall NEHC Performance

low weighted MOE such as staff utilization and improving the score on a high weighted MOE such as cycle time.

Finally, the MAU model, in conjunction with the process flowchart, the simulation model and the probability trees, can be used to help validate modified or customized NEHC designs that each city may desire to implement.

CONCLUSION

This paper provides a description of the efforts of the BW Improved Response Program to develop a flexible emergency response to acts of biological terrorism. It also provides a validation methodology that is based on sound operations research methods and tools, and describes how the methodology will be used to validate the first template component—the NEHC.

The proposed validation approach is important for several reasons. First, the approach will help insure that the template component designs will work under a variety of scenarios. Second, the approach is flexible enough to allow cities and communities to make modifications to the template and conduct their own validation processes that can be compared to the baseline template design.

Lastly, the approach provides a new validation "paradigm" for the nuclear, biological and chemical defense community. Traditional validation approaches for new operational concepts typically involve a field exercise with participants, observers and evaluators providing feedback, qualitative assessments and lessons learned. The BWIRP validation methodology integrates live exercises, expert judgment and operations research models to provide a validation "platform" that can be reused to find concept improvements, test new assumptions, and conduct user training.

The plans to complete NEHC validation testing in 1999 and beyond involve four related activities. The BWIRP will conduct a live field exercise to collect data on the internal "quantity" validity measures. For the "quality" measures, the program will hold a desktop exercise with a select group of independent subject matter experts. An additional set of desktop exercises will be held to validate the component design across a range of potential scenarios. Finally, external validity will be assessed as part of future template component testing.